Opinionated article

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Seeing the light in energy use

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As photonics researchers work from home, and as we enter the first stages of re-entry into our laboratories, the COVID-19 pandemic has reminded us of two things: 1) meeting global challenges requires globally scalable solutions and 2) infrastructure is important. The current health pandemic, uppermost on everyone's mind at present, is a cautionary reminder of other worldwide challenges—foremost being the need to promptly begin an energy transition to a future steady-state of net-zero carbon energy use and eventually to secure large-scale methods for stabilizing our planet's temperature. What does photonics have to do with this transition? Growth in solar energy is one of the biggest good news stories about photonics science and technology that almost no one seems to be remarking!

Solar energy conversion, which in its current form means the solar photovoltaics industry, has quietly risen to be the world's largest optoelectronics industry—>$150B in 2020 [1, 2]—rivaling in size and turnover the display industry [3] but growing faster, and much larger than, e.g., the solid-state lighting and fiber-telecommunications industries. During 2019–2020, and continuing during the COVID-19 lockdown, renewable energy consumption in the United States passed energy consumption from coal for the first time in 130 years. In this time period, among renewable electricity generation sources in the United States (wind, solar, geothermal, biomass and hydropower), solar photovoltaics grew faster than any other source. Both in the United States and around the world, growth in solar photovoltaic energy systems have been quietly dominating new investments in energy generation. The reason: generating electricity using solar photovoltaics is now less expensive in many locations than using any fossil fuel. You might object and say "What about electricity storage? The sun does not shine at night, and so you will need a way to store electricity". Indeed, this is true. However, recent power purchase agreements for electricity generation systems based on solar-plus-battery-storage are also underbidding competing proposals for electricity generation from fossil fuels [4].

What does the future for solar energy conversion hold, and how can photonics researchers have an impact in this vitally important field? I foresee three areas as exciting opportunities for research, with potentially large impacts on world energy use.

First, we need to increase the efficiency of photovoltaics and accelerate the penetration of photovoltaics in the energy sector. Increasing the efficiency of solar cells touches immediately on fundamental photonics and physics issues, such as the flux balance of absorbed and emitted light and the radiative quantum efficiency of materials. It also harbors opportunities for nanophotonic design in light trapping, in creating antireflection coatings for solar cells—and even in giving solar cells distinct bright colors when, for instance, they are incorporated into building architectural facades.

Second, we can learn to emulate nature's amazing feat of photosynthesis: harvesting solar photons and converting the generated charge carriers into products including fuels, chemicals and polymeric materials. This field of solar fuels blends the primary disciplines of chemistry, physics and engineering, and has many opportunities for photonic design. The photonics challenges include harvesting and exploiting the full solar spectrum and enabling nanophotonic design to create efficient systems that combine semiconductors for light absorption, with often optically opaque catalysts for chemical conversion.

Finally, as our planet warms, one of the biggest challenges for humankind is staying cool. Globally, tropical and equatorial regions are experiencing the fastest growth in population and gross domestic product. Recently, in aggregate worldwide, increases in energy use for cooling have surpassed increases in energy use for heating [5]. The concept of radiative cooling by photonic design, in systems that couple energy from blackbody absorbers at the Earth's surface to the 3 K thermal reservoir in the sky, has rapidly advanced in the research literature over the last few years. If efficient and deployable radiative cooling systems could be developed, this science concept could transform into a technology innovation substantially offsetting increases in global energy use.

As photonics researchers emerge from the COVID-19 lockdown, there is an opportunity to reflect on the future

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challenges facing our use of energy. There is a great deal to be done, with the promise of a large impact on our world.

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